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REFORESTATION RESEARCH FINDINGS IN NORTHERN WISCONSIN AND UPPER MICHIGAN

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
CHOICE OF SPECIES	1
Survival	2
Height Development	2
Recommendations	2
Direct Seeding in the Field	5
FACTORS AFFECTING SUCCESS OF SEEDING AND PLANTING	5
Kind of Planting Stock	5
Stock Balance	9
Stock Grading	9
Season of Planting	9
Ground Preparation and Methods of Planting	12
Climate, Soil, and Moisture Conditions	15
Animals, Insects, and Diseases	17
Competing Vegetation	20
The Release Problem	23
UNDERPLANTING ASPEN OR OTHER TREE GROWTH	27
A SITE CLASSIFICATION FOR DETERMINING CHOICE OF SPECIES AND AGE CLASS OF PLANTING STOCK	29
SUMMARY	31
PREVIOUS PUBLICATIONS ON THIS SUBJECT	33
COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED IN TEXT	34

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By J. H. Stoeckeler and G. A. Limstrom 3/

More than three million acres are estimated to be in need of reforestation in northern Wisconsin and Upper Michigan.4/ Past experience has developed workable methods of tree planting, but, in view of the huge program required, the most efficient practice known should be followed. To help answer the basic questions of what, when, and where to plant in this region, a number of pilot-plant or exploratory plantings were made between 1937 and 1942, during the days of the Civilian Conservation Corps. These included 490 acres of exploratory plantings involving more than 681,000 trees on 135 plots on the Nicolet and Chequamegon National Forests in northern Wisconsin -- supplemented by additional tests between 1942 and 1949 -- and several plantings on the Upper Michigan National Forest near Manistique. These plantings provided valuable data on comparative survival, growth rate, and ability of the various species to endure shade, competition, drought, excessive exposure, and other factors in their early years. The results and conclusions of these tests are summarized in this report. They provide information more local in application than that given in the recent bulletin, "Forest Plantations in the Lake States."4/

CHOICE OF SPECIES

What species to plant usually is the first question confronting an owner after he decides his land needs reforestation. Naturally he wants the species which will give the best survival, growth, and value production on his area.

1/ Maintained at University Farm, St. Paul 1, Minnesota, in cooperation with the University of Minnesota.

2/ Credit is due to E. E. Aamodt and J. W. Jay, U. S. Forest Service, who installed some of the plots on which this report is based. The vital contribution of the Civilian Conservation Corps is also acknowledged, for it furnished the man power necessary for plot layout and tree planting. Others contributing to the work are C. F. Arbogast and M. L. Heinselman, Lake States Forest Experiment Station; A. L. Nelson, N. T. Samson, G. R. Condit, and F. W. Stearns, formerly of the U. S. Forest Service.

3/ Forester in Charge, Northern Lakes Forest Research Center, Lake States Forest Experiment Station, Rhinelander, Wisconsin; and Forester, Central States Forest Experiment Station, Columbus, Ohio, respectively (formerly at the Lake States Forest Experiment Station).

4/ "Forest Plantations in the Lake States," by Paul O. Rudolf, U.S.D.A. Tech. Bul. 1010, 171 pp., illus., August 1950.

Survival

The four species most planted on the National Forests of Wisconsin have been red pine, jack pine, eastern white pine, and white spruce.5/ Their survivals in the pilot plantings have usually been quite satisfactory for the older age classes and better grades of stock planted on the proper sites. Survivals were about the same for seedlings and transplants of jack and white pine six years after planting. For red pine, and white spruce the advantage of transplants over seedlings was more striking (table 1). White pine on the experimental plots had much mortality between the eighth and ninth year because of blister rust.

Black spruce shows promise of adaptation to moister and less fertile sites than white spruce. Norway spruce has done rather poorly, due to winter injury and other causes. Once proper seed sources have been determined, it will probably make a better showing. Of six species of hardwoods, red oak and basswood show some promise, white ash and rock elm were somewhat poorer, while sugar maple and yellow birch have done very poorly because of rabbit and deer damage and competition.

Survivals and heights for Scotch pine (tables 1 and 2) are surprisingly good. This species has not, however, been planted extensively on the national forests of Wisconsin because of its tendency to crooked growth in later years. If proper seed sources can be found, based on provenience trials, it may have some possibilities in northern Wisconsin, at least for Christmas tree production.

Height Development

The differences in initial growth between species are quite striking. Jack pine (table 2) grew most rapidly, followed by red and white pines. White spruce grew slowly for the first six years after planting, but thereafter its growth rate improved steadily.

Black spruce transplants at ten years of age were more than twice as tall as comparable Norway spruce stock (table 2).

At ten years of age transplants of jack pine, white pine, red pine, and white spruce, averaged somewhat taller than seedlings of the same species (table 2). On a percentage basis, the advantage of transplants was most striking for white spruce and red pine.

Of the broadleaf species which were planted, basswood and white ash seedlings had the best growth rate followed by red oak (table 2). Rock elm and sugar maple both grew very slowly.

Planted stock grew much faster than did seeded trees of deciduous species.

Recommendations

Considering both survival and height growth in the exploratory plantings and making due allowance for potential market value, the best species for reforestation on suitable sites in northern Wisconsin appear to be red pine, white spruce, black spruce, and jack pine.

5/ Scientific names of trees mentioned in the text are listed at the end of this paper.

Table 1.- Survival first 10 years of 13 species planted or seeded in northern Wisconsin

Species	Class of stock	Survival - various years after planting									
		1	2	3	4	5	6	7	8	9	10
		Percent									
Jack pine	Seedlings	88	82	78	74	72	71	70	69	69	69
	Transplants	95	91	89	87	86	85	84	83	83	83
	Average	92	87	84	81	79	78	77	76	76	76
Red pine	Seedlings	79	74	70	67	65	64	63	63	62	61
	Transplants	94	89	88	86	85	84	83	82	82	81
	Average	86	82	79	77	75	74	73	72	71	70
White pine	Seedlings	89	85	82	81	80	80	79	75	63	-
	Transplants	96	92	90	88	86	86	85	81	63	-
	Average	92	89	86	84	83	83	82	78	63	-
Scotch pine	Transplants	93	89	87	86	85	85	85	85	85	85
White spruce ...	Seedlings	83	74	66	62	57	54	52	48	46	-
	Transplants	92	86	83	81	79	77	76	75	75	-
	Average	88	81	75	72	68	66	63	62	61	-
Black spruce ...	Seedlings	85	75	67	62	55	52	48	46	44	43
	Transplants	96	92	88	85	82	80	78	77	76	75
	Average	92	85	80	74	70	66	63	62	59	58
Norway spruce ..	Seedlings	92	83	76	71	65	62	58	56	54	52
Red oak	Seedlings	93	85	80	75	71	67	64	62	60	58
	Seeded U [x]	55	48	45	43	42	42	41	40	39	38
White ash	Seedlings	81	65	55	47	42	37	35	34	33	32
Sugar maple	Seedlings	77	67	45	35	29	22	19	16	13	12
Basswood	Seedlings	88	82	77	73	71	68	66	64	63	62
	Seeded S [xx]	32	21	15	12	10	8	8	7	7	7
	Seeded U [x]	19	9	6	5	4	4	4	4	4	4
Rock elm	Seedlings	85	72	61	53	47	42	38	35	33	32
	Seeded U [x]	24	16	12	10	9	8	7	6	6	6
Yellow birch ...	Seedlings	70	48	37	29	23	19	16	13	12	11
	Seeded U [x]	27	9	4	3	2	2	2	2	1	1

x Seed spots unscreened.
xx Seed spots protected by conical screens.

Table 2.- Height development first 10 years of 13 species planted or seeded in northern Wisconsin

Species	Class of stock	Average height - various years after planting									
		1	2	3	4	5	6	7	8	9	10
		Feet									
Jack pine	Seedlings	.4	1.1	1.9	2.7	3.7	4.9	6.2	7.6	9.0	10.3
	Transplants	.9	1.7	2.6	3.4	4.8	6.1	7.4	8.8	10.3	11.5
	Average	.7	1.4	2.2	3.1	4.2	5.5	6.8	8.2	9.8	10.9
Red pine	Seedlings	.5	.7	1.0	1.3	1.8	2.3	2.8	3.4	4.2	5.0
	Transplants	.6	1.0	1.4	1.8	2.4	3.0	3.8	4.5	5.4	6.4
	Average	.6	.8	1.2	1.6	2.1	2.6	3.2	3.8	4.6	5.6
White pine	Seedlings	.4	.7	1.1	1.5	1.9	2.3	2.9	3.5	4.3	-
	Transplants	.6	1.0	1.4	1.9	2.3	2.9	3.5	4.2	5.0	-
	Average	.5	.8	1.2	1.7	2.1	2.6	3.2	3.8	4.6	-
Scotch pine ...	Transplants	.7	1.1	1.6	2.2	3.0	3.7	4.8	5.6	6.8	8.0
White spruce ..	Seedlings	.3	.4	.6	.8	1.0	1.3	1.6	2.0	2.5	-
	Transplants	.6	.8	1.0	1.2	1.6	2.1	2.5	3.0	3.8	-
	Average	.4	.6	.8	1.0	1.3	1.7	2.1	2.5	3.1	-
Black spruce ..	Seedlings	.8	1.1	1.3	1.6	2.0	2.3	2.7	3.1	3.5	4.0
	Transplants	1.0	1.3	1.6	1.9	2.3	2.7	3.1	3.6	4.3	5.0
	Average	.9	1.2	1.5	1.8	2.1	2.5	2.9	3.3	3.9	4.5
Norway spruce .	Transplants	.5	.6	.8	.9	1.1	1.3	1.5	1.7	1.9	2.2
Red oak	Seedlings	.4	.6	.8	1.1	1.3	1.6	1.9	2.3	2.7	3.2
	Seeded	.2	.4	.6	.8	1.0	1.2	1.6	1.9	2.3	2.7
White ash	Seedlings	.5	.7	.9	1.1	1.4	1.7	2.0	2.5	3.0	3.7
Sugar maple ...	Seedlings	.5	.6	.7	.8	.9	1.1	1.2	1.4	1.7	2.0
Basswood	Seedlings	.4	.5	.7	.9	1.2	1.5	1.8	2.3	3.0	3.9
	Seeded	.1	.1	.1	.2	.3	.5	.7	.9	1.3	1.7
Rock elm	Seedlings	.5	.6	.7	.8	.9	1.0	1.1	1.3	1.5	1.7
	Seeded	.2	.2	.2	.3	.3	.4	.5	.6	.7	.8
Yellow birch ..	Seedlings	.7	.9	1.1	1.3	1.4	1.7	1.9	2.2	2.5	2.9
	Seeded	.1	.2	.4	.6	.7	.9	1.1	1.3	1.6	1.9

White pine shows promise but should be confined to sites that are kept free of ribes, particularly where white pine is the major species in the plantation. However, a certain percent of white pine in group-wise mixture probably will escape infection in spite of no ribes eradication and will add value both silviculturally and economically to the stand.

One or two-year seedlings of red oak and basswood appear promising enough in northern Wisconsin to warrant planting them on a pilot plant scale on sites where deer populations are rather low. Yellow birch has been disappointing in the plantations because of heavy injury from rabbits, deer, and frost.

Direct Seeding in the Field

Direct seeding holds forth the lure of successful reforestation without the expense of growing and planting nursery stock. Therefore it has been tried frequently. However, direct seeding tests in northern Wisconsin have been failures in about 9 cases out of 10. The few successes were as follows:

1. Jack pine seeded on a recent burn and followed by one or two growing seasons of adequate rainfall, well-distributed over the growing season. This seeding had 732 trees per acre averaging 4.4 feet in height at the end of 7 years.

2. Jack pine seeded on a sub-irrigated sandy site with permanent water table at 2 to 5 feet below the surface and not subject to excessive fluctuation (figure 1). Black spruce also showed some promise on sub-irrigated sites.

3. Red oak seeded on an open rolling, well drained upland sandy loam had a survival of 61 percent and an average height of 4 feet at the end of 9 years. On more level land where frost danger was more severe, a medium density overstory of aspen and paper birch was necessary for best results.

4. Balsam fir direct seeded on disked strips with a thin aspen overstory left for shade, had a stand of 650 to 800 seedlings surviving at the end of two years, supplemented by three to four thousand aspen sprouts and seedlings per acre. The sprouts and seedlings of aspen originated as a result of the stimulation by disking. Results have also been promising with seed spotting in small openings in hardwoods.

FACTORS AFFECTING SUCCESS OF SEEDING AND PLANTING

Aside from choice of species many factors affect the survival and growth of planted or seeded trees. Both the condition of the trees themselves and the environment in which they are placed play important roles. Some of the factors noted in the pilot plantings are discussed below.

Kind of Planting Stock

The age class and size of planting stock has an important bearing on relative field survival of the trees. For the four species tested (jack pine, red pine, white pine, and white spruce) consistently better survivals were obtained for the older age classes (tables 3 and 4). In many cases, however, the superiority of the older

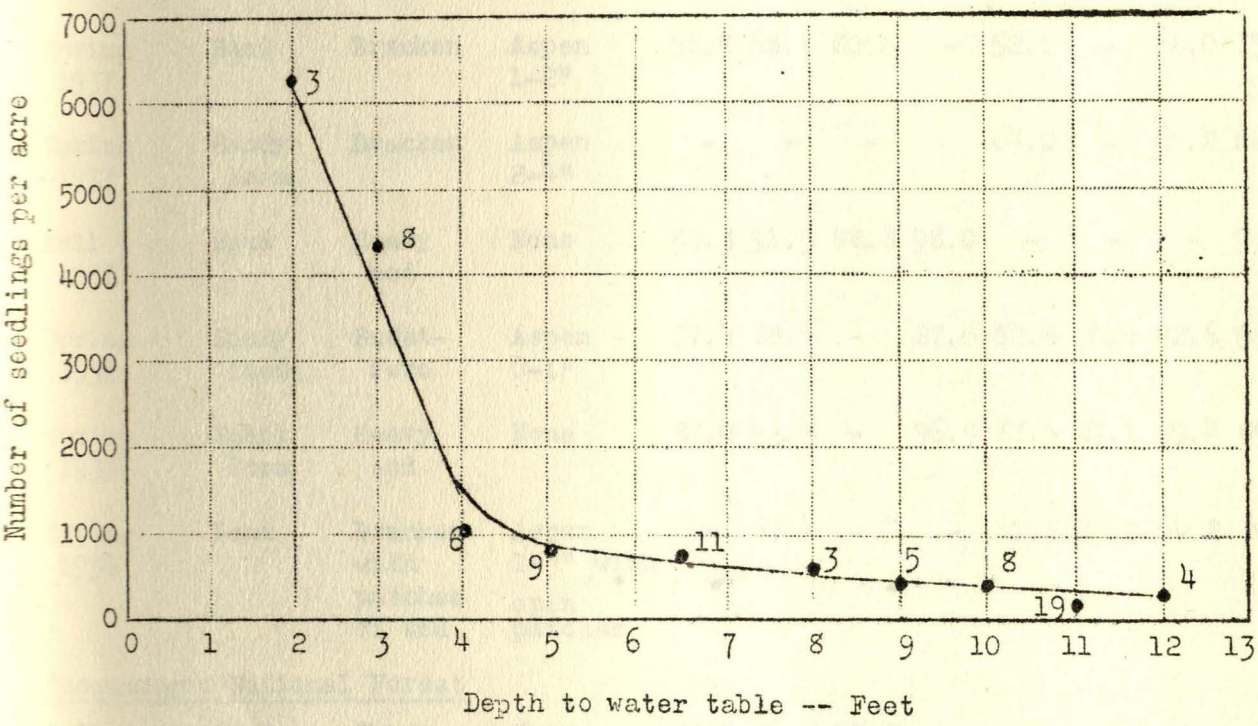

Figure 1.- Survival of jack pine as related to depth of water table in a direct seeding experiment at the end of the second growing season in the field. Figures opposite each point represents number of counting plots averaged for that value.

Table 3.- Comparative survival of red pine and jack pine on various sites 1/

Season and year of planting	Texture of soil	Ground cover	Overstory	Trees living at end of third season							
				Jack pine				Red pine			
				1-0	2-0	1-1	1-2	2-0	3-0	2-1	2-2
				Percent				Percent			
Nicolet National Forest											
Spring 1937	Sand (upland)	Heavy sod	None	22.3	22.3	27.7	-	7.6	-	9.4	27.8
Spring 1937	Sand (subirrigated)	Heavy sod	None	71.3	80.0	79.4	-	56.4	-	61.8	79.4
Spring 1937	Sand	Bracken	Aspen 1-2"	58.8	68.7	80.1	-	52.1	-	61.0	75.3
Spring 1937	Sandy loam	Bracken	Aspen 2-4"	-	-	-	-	64.0	-	64.2	66.2
Fall 1937	Sand	Heavy sod	None	89.3	91.3	98.8	98.0	-	-	-	93.3
Spring 1938	Sandy loam	Sweet-fern	Aspen 0-1"	77.4	88.6	-	87.6	82.4	90.6	92.6	95.5
Spring 1938	Sandy loam	Heavy sod	None	87.0	93.3	-	96.9	87.5	87.1	89.4	89.7
Spring 1938	Loam	Bracken with patches of sod	Aspen 1-3" with open patches	-	67.4	-	-	61.8	63.0	64.2	72.5
Chequamegon National Forest											
Fall 1937	Sand	Heavy sod	None	91.0	96.5	99.7	-	-	-	-	-
Fall 1937	Sand	Heavy sod	Oak 1-3"	83.0	91.8	97.2	-	-	-	-	-
Fall 1937	Loam	Heavy sod	Hdwd. 1-2"	-	76.2	-	-	-	61.5	76.9	-
Upper Michigan National Forest											
Spring 1939	Sand	Heavy sod	None	-	-	-	-	88.0	66.8	91.0	95.3

1/ Basis: Four or more replications of 100 or more trees each for each species and age class on each site; making a total of 45,200 trees.

Table 4.- Comparative survival of white pine and white spruce on various sites 1/

Season and year of planting	Texture of soil	Ground cover	Overstory	Trees living at end of third season											
				White pine					White spruce						
				2-0	3-0	1-1	2-1	2-2	2-0	3-0	2-1	3-1	2-2	3-2
				Percent					Percent					
Nicolet National Forest														
Spring 1937	Sandy loam	Bracken	Aspen 2-4"	72.5	-	71.3	73.7	-	54.0	50.6	75.7	68.8	-	-
Fall 1937	Loam	Sweet-fern & bracken	Aspen 1-2"	71.2	46.4	-	81.5	95.2	-	-	-	-	-	-
Spring 1938	Sandy loam	Sweet-fern	Aspen 0-1"	88.0	-	-	95.0	95.7	-	-	93.9	-	96.4	-
Spring 1938	Sandy loam	Heavy sod	None	86.8	-	-	91.9	-	-	-	-	-	89.5	-
Spring 1938	Loam	Bracken with patches of sod	Aspen 1-3" with open patches	75.6	74.9	-	79.0	87.3	71.8	-	75.7	73.0	85.4	84.1
Chequamegon National Forest														
Fall 1937	Loam	Heavy sod	Hdwds. 1-2"	-	-	-	76.6	-	-	-	70.3	73.5	-	-
Fall 1937	Sandy loam	Bracken	Aspen 2-5"	-	-	-	83.1	-	-	-	87.7	83.7	-	-

1/ Basis: Four or more replications of 100 or more trees each for each age class of each species on each site, making a total of 28,600 trees.

stock is not enough to justify its extra cost. Since cost of planting stock is a consideration along with speed of planting, the possibility should not be overlooked of using bar planting with seedling stock, especially on rough or rocky terrain where machine planting is infeasible and where competition is not severe. On the other hand, where competition is heavy and where dangers of smothering from leaf litter are prevalent, the larger transplant stock usually gives enough better results to justify its cost.

Stock balance (the relation of amount of top to root) also is important, especially in fall planting. For example, a well-balanced[6/] lot of 2-0 jack pine survived well in both fall and spring plantings, whereas a poorly balanced lot gave low survival when fall-planted but fairly good survival when spring planted (tables 5 and 6). Top heavy 3-0 red pine and white pine have shown similar poor results in fall planting (table 8).

Stock grading. Studies indicate a strong advantage in field survival through discarding the smallest, poorest trees in the usual nursery run of seedling jack or red pine stock.

In one trial 2-0 red pine was graded into large, medium, and small classes of stock. The small grade, constituting about 30 percent of the average run of trees, had a stem caliper of 4/64 inch at the ground line. The medium and large grades, respectively, averaged about 5/64 and 6/64 inches in stem caliper. After ten years in the field the small stock had much poorer survival than the larger grades (table 7). These trees had undergone a severe drought in the first growing season after planting and the weaker trees in the smaller sizes suffered considerable loss.

Even more striking results in favor of discarding the smallest or cull grade of stock were obtained by Pomeroy, Green, and Burkett[7/] in a grading test of jack pine, also made in a period when the first growing season (1936) following planting was adverse because of heat and drought.

Season of Planting

The experiments show that survivals are usually 5 to 26 percent better in spring than in fall planting, particularly for 3-0 red and white pines and $1\frac{1}{2}$-0 or 2-0 jack pine. These kinds of stock commonly are top heavy, and the trees tend to dry out in the fall before snowfall, or in the early spring after the snow has melted and the ground is still cold. (Top pruning in the seedbeds in the spring of the second year improves survival of top heavy $1\frac{1}{2}$-0 or 2-0 jack pine stock planted in the fall.) Average height also is generally a little better for spring-planted trees (table 8). If fall planting must be done, much better results will be obtained with red and white pines by using 2-1 or 2-2 transplants. Even 2-0 stock is superior to 3-0 for fall planting. With jack pine, $1\frac{1}{2}$-0 stock, which is better balanced and shorter stemmed, will usually give better survival than the taller 2-0 stock.

6/ Well-balanced planting stock has a fibrous, compact, well-developed root system, and a comparatively short top without excessive foliage area.

7/ Pomeroy, K. B., Green, F. K., and Burkett, L. B. Importance of stock quality in survival and growth of planted trees. Jour. of For., Vol. 47, No. 9, pp. 706-707, Sept. 1949.

Table 5.- Comparison of well-balanced and poorly-balanced 2-0 jack pine

Type of stock	Length		Stem diameter	Average green weight			Top-root ratio	Trees measured
	Tops	Roots		Tops	Roots	Total		
	Inches	Inches	64th Inches	Grams	Grams	Grams		Number
Poorly-balanced from Nursery A	8.25	8.36	10.30	7.960	1.640	9.600	4.85	1,280
Well-balanced from Nursery B	3.70	8.56	6.08	2.749	.727	3.476	3.78	1,280

Table 6.- Comparative survival of well-balanced and poorly-balanced 2-0 jack pine in fall and spring planting

Type of stock	First year survivals 1/				
	Fall planted stock - 1938				Spring planted 1939
	Test 1	Test 2	Test 3	Average	Test 4
	Percent	Percent	Percent	Percent	Percent
Poorly-balanced from Nursery A	38.4	24.8	52.3	38.5	84.2
Well-balanced from Nursery B	93.8	88.0	92.3	91.4	96.2

1/ Basis: Experimental planting of 51,200 trees, half from each nursery.

Table 7.- Survival and height of graded 2-0 red pine planted in a drought year [1/]

Size of stock [2/]	Survivals			Height		
	First year	Second year	Tenth year	First year	Second year	Tenth year
	Percent	Percent	Percent	Feet	Feet	Feet
Large	56.2	44.1	35.7	.34	.43	5.00
Medium	57.1	36.5	31.9	.25	.38	4.70
Small	48.2	29.1	23.3	.19	.26	3.70

1/ Basis: Five replications of 200 trees each for each size of stock, or a total of 3,000 trees.

2/ The percentage of field-run stock represented by the three grades are: large, 25 percent; medium, 39 percent; and small, 31 percent. Culls amounting to 5 percent of the total were not tested for survival.

Table 8.- Sixth year results of fall versus spring planting [1/]

Eagle River District, Nicolet National Forest, Wisconsin

Species	Class of stock	Survival			Average height	
		Fall	Spring	Gain by spring planting	Fall	Spring
		Percent		Percent	Feet	Feet
White pine . .	3-0	58	82	+24	2.87	3.03
White pine . .	2-0	71	78	+ 7	2.32	2.44
White pine . .	2-1	83	88	+ 5	2.69	2.90
Red pine . . .	3-0	42	62	+20	2.28	2.60
Red pine . . .	2-0	56	62	+ 6	2.32	2.37
Red pine . . .	2-1	68	70	+ 2	2.69	2.53
Jack pine . .	1½-0	57	83	+26	4.90	4.92
Average of all species		62	75	+13	2.87	2.97

1/ Basis: Five or more replications of about 500 trees for each age class and season of planting. Total 32,000 trees.

Top pruning of dormant trees or two-year-old wood is not recommended. In some tests there was a loss in first-year field survival of about 20 percent because of top-pruning the 2-0 jack pine just before field planting.

Ground Preparation and Methods of Planting

Ground preparation may be done by furrowing, scalping, or disking. On most types of planting sites found in northern Wisconsin, ground preparation improves the rate of planting, initial survival, and growth.

Furrowing with special Killefer plows has been the usual method of ground preparation. On stony or steep sites "scalping" of 12- to 18-inch squares of sod or other ground cover has been used. On recent burns or areas with thin sod or brush cover, satisfactory results have been obtained without ground preparation. Several types of mechanical tree planters have also been used without advance ground preparation.

An experiment on an upland sandy loam involving two types of scalps as compared with furrowing showed considerable advantage in both survival and growth for three different species of pine when planted in furrows; spruce, however, showed better survival in scalps (table 9). Height growth ten years after planting generally was slightly better in furrows than in scalps (table 9).

In another experiment, large 2-3 white pines were planted on a sandy loam soil with a medium density overstory of 2- to 5-inch d.b.h. aspen, and a ground cover of considerable hazel brush. Very little sod was present. Half of the trees were planted in scalps, and half without ground preparation, with resulting survivals of 65 and 78 percent, and heights of 25.8 and 26.3 inches, respectively at end of the third year in the field. On this easy planting chance with little or no sod, and by use of large transplant stock, scalping was not needed.

Similarly, good results were obtained on a recent burn in hardwood slash, covered with a moderately dense stand of young aspen suckers and seedlings, but almost completely devoid of sod. The trees were planted without making scalps or furrows. Ninth year survivals for red pine were 80 percent, white pine 59 percent, jack pine 77 percent, and white spruce 87 percent. Heights of these species at the end of nine years were 4.3, 3.6, 10.0, and 3.0 feet respectively.

In another experiment, several methods of ground preparation were tried along with planting methods on a poorly drained silt-loam soil on the Chequamegon National Forest. The area was furrowed at intervals of 12 feet and between the furrows, rows of 18-inch-square scalps were made. Planting was done in scalps, in the furrow bottom, and on top of the turned-over furrow slices. Rather outstanding differences were obtained in survival and growth on this wet poorly drained site with by far the best results being obtained by planting on the turned-over furrow slice as compared with the scalp or furrow bottom (table 10). Not only were survival and growth better, but the trees on the furrow slice had better color and appeared more vigorous. Some species, notably yellow birch and red oak, were very sensitive to the excess moisture in the scalps and furrow bottoms.

Table 9.- Effect of ground preparation on survival and growth[1/]

Species and class of stock	Tenth-year survival			Basis, trees	Average height at ten years		
	Standard scalps	Special scalps	Furrows		Standard scalps	Special scalps	Furrows
	Percent	Percent	Percent	Number	Feet	Feet	Feet
2-0 and 1-0 jack pine	53.3	62.9	72.0	10,941	10.4	11.7	12.5
2-0 red pine	36.6	41.9	45.0	10,421	4.8	5.6	5.9
2-0 white pine	45.1	44.0	49.2	11,214	5.0	5.1	5.2
3-0 white spruce	39.1	29.9	26.7	15,042	4.1	4.3	4.7
2-3-1 Norway spruce	-	55.0	47.7	2,394	-	6.9	5.7
3-0 European larch	-	-	27.2	1,440	-	-	5.1
Red oak seed	-	-	8.1	4,183	-	-	2.9

1/ Based generally on two or more replications usually of 1,500 or more trees for each method of ground preparation and species. Standard scalps were about 24 inches square. Special scalps of the same size but all roots to a depth of 8 inches were removed.

Table 10.- Effect of micro-relief and ground preparation on survival and growth on low, wet, heavy soils 1/

Species	Class of stock	Survival at end of 8 years			Average height at 8 years		
		Planted on top of furrow slice	Planted in scalp	Planted in bottom of furrow	Planted on top of furrow slice	Planted in scalp	Planted in bottom of furrow
		Percent	Percent	Percent	Feet	Feet	Feet
Black spruce	2-0	54.0	42.5	42.5	4.3	2.5	2.4
White spruce	2-2	79.0	46.8	49.5	3.7	2.3	1.7
Norway spruce	3-2	61.5	32.8	29.0	1.7	1.6	1.4
White pine	2-2	47.5	26.7	19.5	1.6	1.4	1.4
Black spruce	Seed	21.0	3.7	20.0	1.0	.5	1.1
Hemlock	3-1	5.0	1.0	3.5	.6	.6	.6
White ash	2-0	57.0	20.0	29.5	4.8	3.5	2.4
Red oak	1-0	68.0	27.5	11.0	2.1	1.2	1.4
Red oak	Seed	18.0	9.3	7.0	1.6	1.6	1.2
Yellow birch	3-0	18.5	1.0	0.0	4.3	2.3	0.0
Basswood	2-0	8.0	1.0	0.0	1.4	1.2	0.0

1/ Basis: Two or more replications of 100 trees each for each species in each planting site, making a total of 8,800 trees.

Survival counts for direct seedings are based on number of seed spots occupied.

White spruce, 3-2, planted on an upland area by the inverted "V", side-hole, and spade-slit methods had sixth-year survivals of 85, 84, and 77 percent respectively. Trees in all plots averaged 1.9 feet high. The rate of planting per man-hour was 44, 54, and 120 trees respectively for the three methods. The marked increase in production per man-hour by spade-slit planting despite somewhat lower survival gives it an economic advantage. However, later development of the stands, with possible detrimental effects of slit planting, must be awaited before final evaluation of results.

Climate, Soil, and Moisture Conditions

Climate, soil, and moisture conditions have a very important bearing on the survival and growth of planted trees.

Normality and distribution of precipitation during the first two growing seasons was the single most important factor in survival. As an illustration a test plantation made in a year of normal rainfall, had double to treble the survival of another made in the same area in a drought year (table 11).

Direct seedings on open sand plains often fail because of drying out of the surface one or two inches of soil when the seed has just germinated, thus causing death of the tiny plants. This is true even in years of near-normal precipitation in the Lake States.

Heat plays an important role in causing mortality of new plantings on open land, especially of small seedling stock, and in direct seedings. In a 1936 plantation of 1-0 jack pine, 32 percent of the trees were killed by heat. For direct seedings, the loss was even higher, with practically all mortality being caused by heat or drought. Planted stock has thicker bark and is better able to withstand heat than the tender succulent stems of newly germinated seedlings, which die out wholesale in sandy soils where maximum surface temperatures often reach 130° to 150° F. during the heat of the day (figure 2).

Shallow water tables within 2 to 5 feet of the surface may favorably affect survival in drought years. For instance, in a 1937 spring planting first-year survival on upland sand plains was 16 percent for 2-1 red pine and 30 percent for 2-0 jack pine as compared to 71 percent and 81 percent on a site with a shallow water table. Jack pine seeded on an area with a water table at 2 to $3\frac{1}{2}$ feet had 2,300 to 6,200 seedlings per acre at the end of the second year. Where the water table was below 6 feet there were less than 700 seedlings per acre (figure 1).

Frost heaving sometimes causes considerable loss, especially in fall planting on heavy soils. In one instance, in a fall planting of white pine on a silt loam soil, mortality from frost heaving was 14.9, 7.6, 2.5, and 0.6 percent respectively for 3-0, 2-0, 2-1, and 2-2 stock. Spring planting greatly minimizes loss from frost heaving.

Table 11.- First year survival of plantings as affected by normality of rainfall in the first growing season 1/

Species	Class of stock	First-year survival	
		Rainfall 104 percent of normal 2/	Rainfall 34 percent of normal 2/
		Percent	Percent
Jack pine	1-0	84.7	29.2
	2-0	96.6	3/ 29.8
	1-1	97.0	33.2
Red pine	2-2	94.5	4/ 45.1

1/ Basis: Rainfall 104 percent of normal - eight replications of 100 trees each for each age class of each species, or a total of 3,200 trees. Rainfall 34 percent of normal - ten replications of 100 trees each for each age class of each species, or a total of 4,000 trees.

2/ Rainfall is expressed as percent of normal (17.4 inches) for 5-month period, May to September inclusive.

3/ Drought killed 34 percent of the trees and white grubs 27 percent.

4/ Drought killed 23 percent of the trees and white grubs 31 percent.

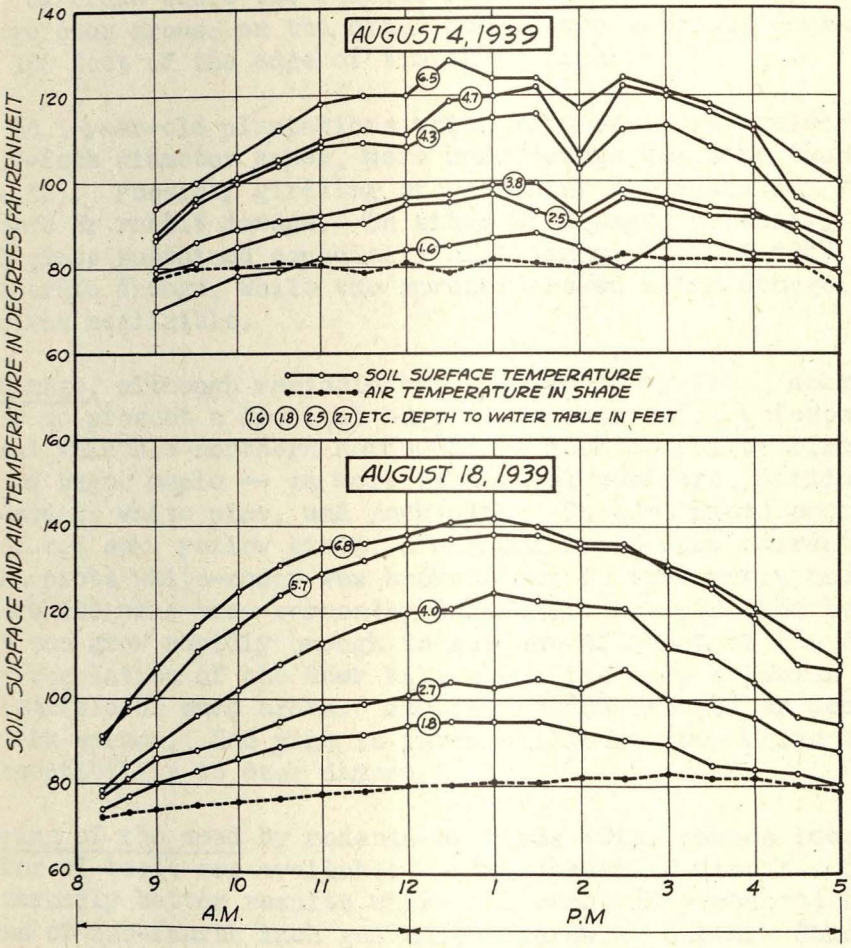

Fig. 2.-Soil surface temperature in furrows in a fine sand soil as affected by depth to a permanent water table.

Animals, Insects, and Diseases

Locally, biotic factors may cause serious mortality or injury to plantations and may govern the feasibility of planting.

Snowshoe hares and cottontail rabbits cause considerable damage to young forest plantations, especially those made on areas with an overstory of aspen, paper birch, or brush where the rabbits find protective cover. New plantings made in large open areas, on the other hand, were scarcely damaged except within 50 to 100 feet of the edge of timber or brush.

In 1- to 3-year-old plantations which were partially released by cutting scrubby 1- to 4-inch diameter aspen, more hare damage was done than in unreleased areas (table 12). Possibly girdling or poisoning the overstory trees would result in less hare or rabbit damage. On sites with aspen or cherry cover, jack and Scotch pines sustained especially high damage, followed by white pine. Red pine had moderate damage, while the spruces showed minor damage. On open sites damage was negligible.

Deer damage, although variable has been so heavy where deer populations were high as to present a distinct barrier to successful reforestation with some of our most valuable northern hardwoods -- such as yellow birch, basswood, red oak, and sugar maple -- as well as several conifers, particularly northern white-cedar, white pine, and jack pine. On some plots over 80 percent of the planted red oak, yellow birch, and sugar maple were currently damaged by deer. On some plots white-cedar was browsed out in five years and up to 29 percent of the white pine were currently damaged. Jack pine has been badly nipped, but it can grow rapidly enough to get out of reach of the deer at an early age. Proper regulation of the deer kill seems the only solution for making reforestation feasible on such areas. Species seldom browsed by deer are white spruce and black spruce. Red pine is intermediate between white spruce and white pine in susceptibility to deer damage.

Pilfering of the seed by rodents or birds often causes losses in direct seeding. A number of tests are available on this phase of direct seeding and they all show markedly better results where the seed was protected by cone-shaped wire screens of one-fourth inch galvanized hardware cloth. Studies in other localities indicate that part of this advantage results from lower soil surface temperature under the screens. The contrast is so striking (tables 13 and 14) that in some cases screening made the difference between initial success and failure of the seeding.

The Saratoga spittle bug injured 21 percent of the 10,900 surviving trees in a 12-year-old plantation of 2-0 jack pine on the Nicolet National Forest. In patches up to half an acre in size as many as 50 percent of the trees were injured. The injured trees were somewhat malformed for three or four years after the attack but seem to have recovered well except in the worst spots. The damage appears to occur mostly on the lighter sandier soils where there is a growth of sweet fern and other herbaceous material to provide host plants for the nymphs. Injury has been most serious on plantations after they have reached seven years in age.

Table 12.- Rabbit injury to plantations as related to species and cover

Nicolet National Forest

Site conditions	Type of treatment	Trees injured by snowshoe hares					
		Scotch pine	Jack pine	White pine	Red pine	Norway spruce	White spruce
		Percent					
Sandy - Medium 3" aspen cover	High release	-	4.0	-	0.5	-	-
	No release	-	2.2	-	0.1	-	-
Loamy soil - Dense 3" aspen cover, some openings	High release	42.6	24.8	21.6	22.0	8.8	1.3
	No release	32.1	12.4	18.1	13.3	0.5	4.4
	Open	26.8	18.7	17.1	11.3	7.0	2.9
Heavy soil - Dense 1" aspen cover	High release	-	-	35.9	-	-	0.6
	No release	-	-	21.2	-	-	0.2
Heavy soil - hardwood cover	High release	-	-	34.2	17.5	-	4.7
Sandy loam - 4" aspen cover	High release	-	-	14.3	6.5	-	0.5
Sandy, upland, 1" pin cherry-aspen	None	-	23.7	5.2	6.3	0.5	0.5
Heavy soil, lowland aspen	None	-	17.3	4.8	8.9	1.0	0.9
Sandy loam, 1" small aspen	None	18.5	59.1	3.1	3.3	0.1	0.0
Loamy soil - open	None	-	0.0	0.0	0.0	-	0.0
Sandy soil - open	None	-	0.0	-	0.0	-	-
Sandy soil - open	None	0.0	0.0	-	0.0	-	-

Table 13.- First-year survival of direct seeding of conifers as affected by screening against rodents and birds 1/

Species	Seed spots occupied by one or more seedlings 2/		Germination 2/	
	Screened	Unscreened	Screened	Unscreened
	Percent	Percent	Percent	Percent
Jack pine . . .	100	55	43.3	8.2
Red pine . . .	100	55	57.8	5.9
White pine . .	95	90	41.8	14.8
Black spruce .	95	10	7.3	0.8

1/ The site was a sandy area devoid of tree growth and with shallow water table at 1.5 to 3.0 feet. Part of the advantage of the screens doubtless was reduction of soil surface temperatures as well as protection from animals.

2/ Basis: Forty seed spots for each species, half of which were protected with hardware cloth cones. In each seed spot 20 seeds were sown, or a total of 3,200 seeds in the test plot.

Table 14.- First-year survival of direct seeding of broadleaf species as affected by season of sowing and protection from rodents 1/

Species	Season sown	Seed spots occupied by one or more seedlings 2/		Actual germination 2/	
		Screened	Unscreened	Screened	Unscreened
		Percent	Percent	Percent	Percent
Red oak	Fall	100	50	64.0	38.0
	Spring	80	80	26.0	24.0
White ash . . .	Fall	100	40	29.0	6.0
	Spring	50	40	6.0	7.0
Yellow birch .	Fall	90	30	10.5	3.5
	Spring	30	10	2.0	0.5
Hard maple . .	Fall	30	0	4.0	0
	Spring	0	0	0	0

1/ The site was a sandy loam with a fairly dense overstory of one- to two-inch diameter aspen.

2/ Basis: Ten screened and 10 unscreened seed spots for each species in each season, or a total of 160 seed spots. Total seeds planted were 200 red oak, 400 white ash, 800 yellow birch, and 400 hard maple.

The larvae of May beetles (white grubs) may cause heavy mortality in first or second year plantings, especially in years of subnormal precipitation. First year mortalities of 27 and 31 percent have been recorded for 2-0 jack pine and 2-2 red pine respectively when planted in a drought year on sandy land.

The white pine weevil, red-headed sawfly, jack pine sawfly, and pine tip moths all have caused some damage, but in general it has been under five percent in 10-year-old plantations.

White pine blister rust caused serious mortality to white pine plantations between the eighth and ninth years in the field. Infection occurred about 3 to 4 years after planting. Eradication of ribes, the alternate host plant of white pine blister rust was deliberately avoided on these experimental plots to determine just how much of a factor this disease could be in mortality of white pine. The results from these plots are strong proof of the need of eradicating gooseberries and susceptible forms of currants from areas where white pine constitutes the major species planted.

Competing Vegetation

Cover of brush and overstory trees plays a variable role in survival and growth of plantations. In general, intolerant species like jack pine, red pine, and Scotch pine develop poorly under a fairly dense cover of aspen, paper birch, or other broadleaf trees. Even the more tolerant white pine and Norway spruce suffer reduced survival and growth. White spruce tolerates more cover; it may even survive better under aspen or birch than in the open. Direct seeded hardwoods, such as red oak, which are rather sensitive to frost injury may be injured by removal of too much of the overstory.

These observations are illustrated by survivals and heights obtained on an experimental plot which was planted on the Nicolet National Forest in the spring of 1938 under a medium cover of 5-year-old aspen (5,500 stems per acre) and released in 1940 (table 15).

In another instance there was a comparison of intensity of release. This test indicated that jack pine requires heavier release and will tolerate less shade than red pine. Based on tenth-year results there was a distinct advantage in survival and height growth from two releases for jack pine, made two and four years after planting (table 16). Red pine showed very little benefit in survival from the double release but height growth was consistently better for the double than for the single release.

In another instance, a plot involving 1-0 red oak and 2-0 white ash was planted in the spring of 1939 on an area with a fairly dense overstory (about 4,000 stems per acre) of 4-year-old aspen. Four different degrees of release were tried in June 1940. Survival (table 17) at the end of eight years showed clearly that complete removal of the overstory was harmful and that retention of a moderate overstory of aspen doubled or trebled survival due to lessened injury by frost. Average heights in oak were markedly better where some overstory was left. With ash, the contrast in height was not great.

Table 15.- Effect of cover on survival and height of under planting [1/]

Species	Class of stock	Ninth year survival				Average height in ninth year			
		100% rel.	80-90% rel.	50% rel.	No rel.	100% rel.	80-90% rel.	50% rel.	No rel.
		Percent				Feet			
Jack pine	2-0	88.0	86.6	86.7	35.8	11.3	9.9	9.1	1.1
Scotch pine	2-1	100.0	94.3	86.4	63.1	7.7	7.7	6.5	3.6
Red pine	2/	85.6	78.0	91.6	65.0	6.7	6.1	6.6	4.9
White pine	3/	70.4	64.3	57.3	43.6	5.1	4.4	5.2	3.8
Norway spruce	3-1	71.9	62.0	60.6	36.0	2.2	2.2	1.7	1.4
White spruce	4/	91.2	80.3	91.2	86.5	3.7	3.6	4.5	4.1
Red oak	1-0	81.4	79.6	69.7	84.2	2.0	3.8	2.4	1.7
Red oak	Seed	48.7	46.4	57.1	80.6	1.1	1.6	1.9	1.9

1/ "Rel." refers to release. In the released subplots the herbaceous vegetation was reduced around each tree, and the aspen-pin cherry overstory was cut at three intensities -- part of the plot having a 100 percent overstory removal, part a 80-90 percent removal, part a 50 percent removal. The "No release" check area was not given either low or high release.

2/ Average for several classes of stock including 2-0, 3-0, 2-1, 1-2, and 2-2.

3/ Average for several classes of stock including 2-0, 2-1, 1-2, and 2-2.

4/ Average for two classes of stock: 2-1 and 2-2.

Basis: Four replications of 200 trees each for each class of stock. Total 12,800 trees.

Table 16.- Effect of cover on survival and growth of red pine and jack pine plantings 1/

Species	Class of stock	Tenth year survival		Average tenth year height	
		2 releases 1 low and 1 high	1 low release only	2 releases 1 low and 1 high	1 low release only
		Percent		Feet	
Jack pine	1-0	58.3	27.3	9.7	8.7
Jack pine	1-1	76.8	50.5	10.6	9.2
Jack pine	2-0	62.0	51.2	10.4	7.3
Species average		65.7	43.0	10.2	8.4
Red pine	2-0	44.0	50.7	4.2	3.4
Red pine	2-1	57.2	49.0	5.5	4.6
Red pine	2-2	70.5	65.5	6.2	5.3
Species average		57.2	55.1	5.3	4.4

1/ Basis: Two or more replications of 200 trees each for each class of stock, of each species, for each intensity of release. Total of 6,000 trees.

Table 17.- Effect of overstory cover on a hardwood planting 1/

Species	Class of stock	Eighth year survival				Average height in 8 years			
		Uncut	Medium cut	Heavy cut	Clear cut	Uncut	Medium cut	Heavy cut	Clear cut
		Percent				Feet			
Red oak . . .	1-0	65.5	67.5	70.5	35.5	1.8	1.9	2.1	.8
White ash . .	2-0	44.0	68.5	30.0	22.5	2.0	2.6	1.6	1.8

1/ Basis: One plot of 200 trees for each type of release for each species, or a total of 1,600 trees for each species.

A light overstory of aspen or paper birch may be of especial benefit in aiding survival of newly-planted trees in drought years, as illustrated by some plantings made on sandy soils on the Lakewood District of the Nicolet National Forest in 1937 (table 18). In that year, rainfall was 34 percent of normal for the period May to September, inclusive. In this case presence of an overstory made the difference between success and failure.

The release problem

The partial or complete removal of overstory trees and shrubs shading a plantation is usually referred to on the Wisconsin national forests as "release." Such release can be done immediately before or within a year or two after planting. One or two more releases may be necessary at intervals of 2 to 4 years after the initial operation, depending on the growth rate of the planted tree, shade tolerance of the species; vigor, size, and density of the competing brush or weed-tree species; and entomological considerations.

A year or more after planting, trees will theoretically make maximum growth in full sunlight; which would require cutting all overtopping trees and brush. However, maximum growth rate is not the only consideration in deciding the intensity of release. There are specific advantages to retention of some overstory cover of broadleaf species, especially with white pine, spruce, and northern hardwoods.

The relative shade tolerance of the major coniferous species usually planted on the national forests of Wisconsin is as follows in increasing order: 1. Jack pine; 2. Red pine; 3. White pine; 4. White and black spruces.

Jack pine does best in full sunlight and withstands very little shade. It should be freed of practically all overhead competition within a year after planting. A light uniform cover of aspen or brush, allowing about 80 percent of full sunlight, maintained for one or two years after planting is permissible and will reduce mortality in drought years.

Table 18.- Favorable influence of a thin overstory of 1- to 2-inch diameter aspen and paper birch on red pine plantings in a drought year

Class of stock of red pine	First year survival 1/	
	Under cover	In the open
	Percent	Percent
2-0	63.7	14.5
2-1	68.6	16.1
2-2	80.8	45.1
Average	71.0	25.2

1/ Basis: Survival under aspen - Five replications of 200 trees each for each of three age classes, or a total of 3,000 trees. Survival in the open - Ten replications of 100 trees each for each of three age classes, or a total of 3,000 trees.

Red pine is somewhat more shade tolerant than jack pine. A scattered cover of aspen or paper birch may be retained for as long as 10 years provided it allows at least 70 to 80 percent of full sunlight to come through the overstory canopy.

White pine is considerably more tolerant than red pine. In northern Wisconsin it is subject to considerable tip weevil damage which can be reduced by maintaining some overstory of aspen or paper birch until the pine is about 20 to 25 feet tall. The ideal cover which will permit reasonably good growth and yet reduce weevil damage somewhat, allows about 60 to 70 percent of full sunlight to come through the canopy.

White and black spruces tolerate more shade than white pine and have done surprisingly well when planted under thinned out stands of aspen. But even these rather shade-tolerant species are held back considerably in growth if planted under heavy shade; removal of overstory cover is desirable so that at least 50 to 60 percent of full sunlight prevails during the first two or three years after planting. Thereafter, the overstory can be thinned heavily so as to permit at least 60-70 percent or more of full sunlight. Final removal of the overstory aspen and birch in a commercial operation appears entirely feasible on medium and good sites when the overstory stand averages 6 to 10 inches in diameter.

From such evidence as exists on experimental plots, species such as red oak and basswood, underplanted in aspen, can be released in the same manner as spruce.

Release work on the exploratory plots generally has been done with a "Phelps Tool," a light efficient brush knife made from discarded band saw blades. Machetes, brush knives, and brush hooks, have also been used. All work well on stems under about 3 inches in diameter. On material of larger diameter, axes were used. Such release work requires from 8 to 24 man-hours of labor per acre.

The removal of aspen and other deciduous species in release cutting is somewhat more effective if done between late June and mid-August because sprouts are fewer and less vigorous than when cutting is done in the dormant season.

Estimating light intensity, or density of overstory, in connection with the need of release is somewhat difficult in practical application. However, this can be judged indirectly by examining the planted trees closely for growth rate (table 19). If current and past growth rate for several years is below the average, the overstory probably is too dense and needs thinning out. Allowance must be made for droughts or injuries from insects, diseases, animals, or factors other than density of overstory which may have reduced growth. Age class of planting stock also has a bearing in the early years of a plantation. For example, transplants, especially of red pine and white spruce, often grow 30 to 50 percent more in height than do seedlings.

There are also other criteria of suppression besides length of internodes between the whorls of branches. If the stems are unduly spindly in relation to total height or if the needles are short, and their density is thin compared to nearby open-grown vigorous trees, it is quite certain that release cuttings should be undertaken immediately.

Table 19.- Criteria of minimum height growth in forest plantations under an overstory of trees or shrubs on average sites 1/

Species	Average annual height growth		
	Second and third season after planting	Fourth and fifth season after planting	Sixth to tenth season after planting
	Inches	Inches	Inches
Jack pine	6	10	12
Red pine	4	6	8
White pine	4	6	8
Black spruce . . .	3	5	7
White spruce . . .	2	4	6

1/ On poor sites, the values in the table can be reduced by one-fourth; on good sites they may be increased by one-fourth. This table is based on general observations of all exploratory plantings supplemented by measurement and classification of several thousand trees over a range of site conditions.

UNDERPLANTING ASPEN OR OTHER TREE GROWTH

Much of the land in northern Wisconsin is covered with aspen and paper birch, both pioneer species which follow fire and, sometimes, clear cutting. Much of this aspen will become merchantable when 35 to 50 years old, but some of it will not. It would appear to be good economics to plant up the poorer aspen sites, and to harvest a crop of aspen from the well-stocked, thrifty stands on better soils, before attempting their conversion to more valuable species such as pine or spruce. In the meantime, considerable natural conversion, especially by northern hardwoods or balsam fir may have occurred, making it unnecessary to plant some tracts. However, in stands only 5 to 10 years old it is difficult to gauge site quality by ordinary height-site tables, so other means are necessary.

Based on soil texture, uniformity of stocking, and fire history since the aspen became the dominant species on the site, a guide (table 20) has been prepared to help determine which young aspen stands urgently need underplanting. In general, repeatedly burned sites, areas of poor, thin sand; or those with patchy distribution and serious understocking can be set up for underplanting because there is little prospect for producing worthwhile merchantable crops of aspen on these sites. The same general guide can be used for judging which paper birch stands to underplant.

Underplanting is not ruled out on the areas of better soil or good stocking which may produce merchantable aspen, but the need is certainly less urgent. On such sites the aspen can be removed later in commercial thinnings.

The retention of a mixture of 10 to 15 percent of broadleaf species in plantings of spruce and white pine appears worthwhile to improve the soil, lessen insect damage, and increase overall yield.

Underplanting of dense, thrifty, immature aspen stands over 3 inches in diameter has not seemed feasible because of the very high labor cost in thinning them out sufficiently so the underplanted conifers can maintain satisfactory growth.

Areas with scattered or patchy northern hardwood sprouts or seedlings present are worth trying to fill in to bring up stocking of the stand, particularly when as much as one-third to one-half of the land consists of patches of sod land. The better stocked areas of northern hardwood type should not be underplanted.

Table 20.- Planting guide for pure, immature stands of aspen

Age class and distribution	Fire history since establishment of aspen	Soil classes and percent of silt and clay in top two feet of soil				
		Sands 0-15 percent	Loamy sands 15-20 percent	Light sandy loams 20-30 percent	Good sandy loams 30-50 percent	Loams or heavier soil 50 percent or more
Even aged, uniformly distributed with medium or better stocking	Not burned	1/ Plant	2/ Plant	5/	5/	5/
	Lightly, or moderately burned	Plant	Plant	2/ Plant	5/	5/
	Severely burned	Plant	Plant	Plant	Plant	6/
Uneven aged poorly stocked patchy distribution 4/	Burned or not burned 3/	Plant	Plant	Plant	Plant	Plant

1/ If the stand is mostly large-tooth aspen, a soil as low as 10 percent of silt and clay will produce merchantable material if the site has sustained no repeat burns and the aspen is in apparently good vigor.

2/ Do not plant if area has water table 3-7 feet below surface, since aspen is usually merchantable on such sites.

3/ This type is usually burned one or more times since establishment of aspen.

4/ This type usually with open or poor density when stand tally is computed for entire area. Patches may be well stocked.

5/ These areas expected to produce merchantable aspen.

6/ These areas will usually produce some merchantable aspen, but in some cases may need "sweetening" with some planting to bring up stocking.

A SITE CLASSIFICATION FOR DETERMINING CHOICE OF SPECIES AND AGE CLASS OF PLANTING STOCK

The results of the exploratory plantings, observations made on growth and survival of older plantations, and contributions in the field of soil science now provide a fairly good basis for selecting the species and age class of trees suited for specific planting sites on the national forests of northern Wisconsin and adjacent Upper Michigan (table 21). Adequate information is available only for jack pine, red pine, white pine, white spruce, and black spruce on mineral soils.

One class of sites omitted in the table is sphagnum peat swamps and muck land, because work on them is still in the exploratory stage. Based on present knowledge, black spruce is probably the most suitable species for peat swamps, particularly on the better sites where scattered balsam fir, black ash, white pine, and yellow birch are present. Tamarack may have some possibilities on sites where there is little or no overhead cover and where deer and rabbits are not abundant.

In general terms the recommendations are that: (1) Jack pine should be limited to only the poorest sands; it has been planted too liberally in the past on sites which will grow the more valuable red pine. (2) Red pine in turn should be limited to well-drained sands to sandy loam upland soils, or to sandy areas where the water table remains at least 3 to 4 feet below the surface. (3) White pine, where it is to constitute the main stand, should be limited to areas with some overstory and to well-drained soils classed as sandy loams, with the provision that systematic ribes eradication be done. White pine grows well on soils of loam texture, but usually the ribes population is so high on such areas that control measures would be very expensive or prohibitive. A scattering of 10 to 20 percent white pine in white spruce plantings holds some promise without eradication of ribes. White pine is also well adapted to light sandy soils with permanent water tables at 3 to 6 feet. (4) White spruce is suitable for well-drained sandy loams or heavier soils, as well as for certain classes of rather moist, sandy loams or heavier soils in sub-irrigated and on rather poorly drained mineral soils (not true peat swamps). (5) Black spruce is generally suited to the moister sites. It will grow on somewhat poorer soils than white spruce, including sands and loamy sands with permanent high water tables.

Because less information was available no specific recommendations were made for the following species: (1) Norway spruce and Scotch pine cannot be recommended generally until conclusive proof is available of their adaptability from long-range provenience tests now underway. Their soil requirements are similar to those for white spruce and red pine, respectively. (2) Red oak seems to be a good species to try out on former hardwood sites which are on well-drained mineral soils with a silt-plus-clay content of 20 percent or more and which have a protective overstory of aspen or other cover. (3) Basswood seems worthy of trial on well-drained, moderately fertile former northern hardwood land with 30 percent or more of silt-plus-clay. (4) Yellow birch, sugar maple, rock elm, and white ash have not given satisfactory results because of deer and rabbit damage, frost, competition, and other reasons. Their soil demands appear to be similar to those for basswood.

Table 21.- A site classification for determining choice and age class of species for planting on the National Forests in northern Wisconsin, based on silt-plus-clay content, cover, and soil moisture relations 1/

Overhead cover	Density of low ground cover (brush and sod)	Well-drained mineral soils					Poorly drained mineral soils		Mineral soils with shallow water tables at 3-6 feet	
		0-10 light sands	10-20 better sands and loamy sands	20-30 light sandy loams	30-50 sandy loams	50+ loams and heavier soils	Under 20 sands and loamy sands	20+ sandy loams or better soils	Under 20 sands and loamy sands	20+ sandy loams or better soils
Open sites little or no overhead cover of aspen, paper birch or scrub oak	Light to medium	JP.(2-0, 1½-0, or 1-0)	RP. (2-1, 3-0, or 2-0)	RP. (2-1, 3-0, or 2-0) 3/	WS.(2-2) RP.(2-1 3-0) 3/	WS.(2-2)	BS.(2-1)	BS.(2-1) WS.(2-2)	RP. (2-1, 3-0) BS. (2-1) WP. (3-0, 2-0, 2-1)	WS. (2-2) BS. (2-1)
	Heavy	JP.(2-0, 1½-0, or 1-1)	RP. (2-1, 1-2, or 2-2)	RP. (2-2, 1-2, or 2-1) 3/	WS.(2-2) RP.(2-1, 2-2) 3/	WS.(2-2)	BS.(2-1)	BS.(2-1) WS.(2-2)	RP. (2-2, 1-2, 2-1, 3-0) BS. (2-1) WP. (2-2)	WS. (2-2) BS. (2-1)
Sites with an overstory of aspen, paper birch, scrub oak, or other 2/ cover	Light to medium	JP. (2-0, or 1½-0)	RP. (2-1, 1-2, 2-2, 3-0) WP.(2-1, 2-2, 3-0) 3/	RP.(2-2, 1-2, 2-1 3-0) WP.(2-1, 2-2, 3-0) 4/	WS.(2-2) WP. (2-1, 2-2, 3-0) 4/	WS.(2-2)	BS.(2-1)	BS.(2-1) WS.(2-2)	BS. (2-1) WP. (2-2, 1-2, 2-1, 3-0)	WS. (2-2) BS. (2-1)
	Heavy	JP. (2-0, or 1-1)	RP.(2-1, 1-2, 2-2) WP.(2-2, 2-1) 3/	RP. (2-2, 1-2, 2-1) WP.(2-2, 2-1) 4/	WS.(2-2) WP. (2-1, 2-2) 4/	WS.(2-2)	BS.(2-1)	BS.(2-1) WS.(2-2)	BS. (2-1) WP. (2-2, 1-2, 2-1)	WS. (2-2) BS. (2-1)

1/ Values 0-10, 10-20, 20+, etc. refer to silt-plus-clay content of top 2 feet of soil (percent) by Bouyoucos hydrometer method.

2/ Areas with overhead cover must be thinned out shortly before or shortly after planting to crown density not exceeding following: Jack pine, 20 percent; red pine, 30 percent; white pine, 40 percent, black and white spruce, 50 percent.

3/ White pine does well on such sites but because of possibility of attack by white pine weevil or blister rust or of slow growth should generally not constitute over 20 percent of the stand.

4/ White pine usually well adapted providing ribes are eradicated, especially in soils over 20 percent of silt-plus-clay where they may be numerous enough to be a threat as regards white pine blister rust.

SUMMARY

This publication summarizes the results of experimental and pilot plantings made between 1937 and 1949 on 490 acres on the Nicolet and Chequamegon National Forests in Wisconsin and on the Upper Michigan National Forest near Manistique, Michigan.

Among the results brought out are the following:

1. Choice of species for planting or seeding.- Red pine, jack pine, white spruce, and black spruce have given the best results in pilot plantings involving conifers. White pine has done fairly well on sites where ribes, the alternate host of white pine blister rust, were absent or scarce. Where ribes were abundant and no eradication was done, heavy losses were sustained. Northern red oak and basswood have shown best results of any of the broadleaf species planted.

   Except for a few conditions direct seedings usually have been failures. Some measure of success was attained with jack pine on recent burns; jack pine and black spruce on sandy sites with shallow permanent water tables; red oak on well-drained upland sandy loam soils, and balsam fir in small openings in hardwoods, under scattered aspen overstory, and on swamp margins.

2. Factors affecting the success of reforestation

   Class and size of planting stock.- Transplants of white spruce, black spruce, and red pine had an advantage over seedlings of the same species in sixth year survival of 24, 28, and 19 percent respectively. Height growth of the transplants also was strikingly greater than that of the seedlings.

   Stock balance.- Trees which are usually poorly balanced in ratio of weight of top to root such as 3-0 red pine, 3-0 white pine, and any tall spindly 2-0 or 1½-0 jack pine often suffer heavy loss in fall plantings. They are recommended only for spring planting.

   Grading of nursery stock.- By grading 2-0 red pine in the nursery so as to discard the smallest, poorest trees, tenth year field survivals were increased 9 to 12 percent and growth was improved.

   Season of planting.- Spring planting was superior to fall planting especially for 3-0 red pine, 3-0 white pine, and 1½-0 or 2-0 jack pine.

   Ground preparation and methods of planting.- Pine survivals were 4 to 19 percent higher in furrows than in standard scalps. White spruce, however, had 7 to 12 percent better survival in scalps than in furrows. On low, wet, poorly drained mineral soils survival of black and white spruce were increased by 12 to 32 percent and height growth approximately doubled by planting trees on top of the turned over furrow slice rather than in scalps or in furrows.

3. Climate, soil, and moisture conditions.- Normality of rainfall was the single most important factor affecting survival, especially during the first two growing seasons after planting.

Shallow water tables within 2 to 5 feet of the surface of sandy soils favorably influence survival of direct seedings and plantings. On the other hand, surface soil dryness and heat were important causes of early mortality, especially in seedings. Frost heaving caused some losses on heavier soils.

Wildlife, insects, and diseases.- Snowshoe hares and cottontail rabbits caused heavy losses to plantations under cover. Deer damaged northern hardwoods, white-cedar, and white pine so seriously that these trees cannot be recommended for planting where deer populations are high. Pilferage of seed by rodents and birds was an important cause of failure among direct seedings.

The most destructive insects were white grubs and the Saratoga spittle bug. Tip weevils and sawflies caused minor losses.

The white pine blister rust killed many planted white pines between their eighth and ninth years in the field where ribes were not eradicated.

Effect of overstory.- An overstory of aspen generally lowered survival and growth of intolerant species such as jack, red, and Scotch pines. Even white pine and Norway spruce, generally credited with being fairly tolerant, had distinctly lower survival and growth when overtopped by a fairly heavy stand of young aspen. White spruce, however, survived rather well under an overstory of young aspen. Direct seeded red oak showed a marked benefit from the protection against frost provided by a young aspen overstory. In plantings of 1-0 red oak and 2-0 white ash, survival was much better where a partial overstory of aspen was retained than where it was clearcut.

In years of severe drought or heat, a thin overstory of aspen and paper birch greatly increases survival.

Intensity of release.- Ten years after planting under an aspen overstory, jack pine which had been given intensive release had 23 percent higher survival than that not released. Red pine survival was not so sensitive to intensity of release but its height growth was markedly better when under heavy release. The need for plantation release is outlined by species. Timing and frequencies of release are discussed.

4. Underplanting of aspen.- Based on soil texture and fire history a guide to the prospective merchantability of young aspen stands is provided and recommendations are made as to which sites to underplant.

5. Planting site classification.- Species and age classes are recommended for planting according to soil texture, moisture relations, presence or absence of overstory of aspen and other species, and density of the ground cover, particularly brush.

PREVIOUS PUBLICATIONS BASED ON THESE STUDIES 8/

Lake States Forest Experiment Station

Water Tables and Survival. Tech. Note No. 139, 2 pp., mimeo., illus., February 1938.

Deep rooting and plantation survival. Tech. Note No. 140, 2 pp., mimeo., illus., February 1938.

Beneficial effect of partial shade on field survival. Tech. Note No. 144, 1 p., mimeo., April 1939.

Top-root ratio and size of top very important in fall-planted stock. Tech. Note No. 158, 1 p., mimeo., May 1940.

Stoeckeler, J. H. and Sump, A. W.

Successful direct seeding of northern conifers on shallow-water-table areas. Jour. For. 38(7): 572-577. July 1940.

_____ and Limstrom, G. A.

Ecological factors influencing reforestation in northern Wisconsin. Ecol. Mono. 12(2): 191-212, illus., April 1942.

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A site classification for reforestation on the national forests of Wisconsin. Jour. For. 40(4): 308-315. April 1942.

When is plantation release most effective? Jour. For. 45(4): 265-271. April 1947.

Planting poorly drained wet sites. Tech. Note No. 276, 1 p., mimeo., July 1947.

8/ Several of the findings reported in this paper have been issued previously, often in more preliminary or less complete form.

COMMON AND SCIENTIFIC NAMES OF TREES MENTIONED IN TEXT

Common name	Scientific name
Ash, white	Fraxinus americana
Aspen, bigtooth or large-tooth	Populus grandidentata
Aspen, quaking	Populus tremuloides
Basswood	Tilia americana
Birch, paper	Betula papyrifera
Birch, yellow	Betula lutea
Elm, rock	Ulmus thomasi
Fir, balsam	Abies balsamea
Maple, sugar or hard	Acer saccharum
Oak, northern red	Quercus borealis
Oak, northern, pin, or scrub	Quercus ellipsoidalis
Pine, jack	Pinus banksiana
Pine, red	Pinus resinosa
Pine, Scotch	Pinus sylvestris
Pine, eastern white	Pinus strobus
Spruce, black	Picea mariana
Spruce, Norway	Picea abies
Spruce, white	Picea glauca